REMARKS ON UNIFORMITY OF NOMENCLATURE IN REGARD TO MICROSCOPICAL OBJECTIVES AND OCULARS.

BY R. H. WARD, M.D.*

THE *nominal focal length* of an achromatic objective, as used by microscopists generally, represents its amplifying power as actually used in the compound microscope. Even the equivalency in amplifying power with a single lens of the same focus is no longer distinctly realized, while the size and appearance of the combination, its working focus, angular aperture, and microscopical efficiency, are not even hinted by the figures used. The nominal focus represents the magnifying power and those properties dependent on it. Like other measurements, these must be stated by comparison with known standards. To use diverse and unknown units of measurement in cases designed to be compared with each other is simply self stultification. To call two lenses, of identical magnifying power, respectively one-fourth and one-sixth inch lenses, is just as indefensible as to call two houses of equal height, forty and fifty feet high respectively. To argue against the existing looseness of usage in naming lenses, is only to state what everybody knows in regard to the advantages of uniform standards of measurement generally. So impressed are many microscopists with the urgency of this question, and so determined are they to escape from some of the present confusion, that a committee has been appointed to report on the subject. Though that committee is unprepared to report, it is believed that giving publicity to some facts and opinions involved in the consideration, may lead to useful agitation and to increased definiteness of ideas and of information in regard to it. Of course it would be premature to claim or expect accuracy of statement or safety of opinion in such a complication of disputed questions; and what is said, is designed to be contributory and suggestive, and in no degree dogmatic or final.

The great variation in objectives of identical name is familiarly

*Being the substance of remarks made by the writer at the Indianapolis meeting of the American Association for the Advancement of Science.

known and is undisputed. Among other people one-fourth of an inch is less than four-tenths and more than one-fifth; but among microscopists it may often be more than the first or less than the last. An indefinite number of figures might be published to prove or illustrate this irregularity, the writer having been particularly interested in making and recording these comparisons for more than a dozen years, and Messrs. Bicknell, Biscoe, Higgins, Cross, and many others having been especially interested in the same study; but it is idle to prove what everybody knows and admits. So familiar have some of these apparent errors become by use, and good usage too, that they have been often accepted as established, even one of the latest authorities* stating the power of the one-fourth-inch objective five times as high as that of the one-inch.

In the early days of the compound microscope as a really useful instrument, we find microscopists wishing that microscope makers would "grind their glasses to some settled standard."† We are willing to be more reasonable now, or else the conditions stated have become more difficult. We do not desire, nor consider it practicable that the opticians should make all their combinations of certain definite and conveniently graded powers; but we do propose so to name our powers, if we can, that each number shall group together all those powers of which it is the nearest and best description.

Makers would doubtless be considered as doing a favor to those who use their instruments if they would, after finishing lenses, carefully estimate their powers and name them by the fractions most nearly representing those powers. But even if this were done, and much more now when this is certainly not done, or not done upon such a uniform plan as to be satisfactory, microscopists should always reëxamine their lenses in order to be definitely informed in regard to one of their most important properties.

The easiest method of examining the *magnifying power* of an objective, by measuring the image (of a known object) which it forms at a standard distance (now ten inches), was as well understood a hundred years ago as now; a lattice of fine silver wire or of human hair, or a scale ruled on glass, being used to measure

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* Suffolk, Microscopical Manipulation, London, 1870.

† Baker on Microscopes. London. 1742.

the image.* A positive ocular† or the eye-lens of a negative one is used as a simple microscope with which to read off the measurement. If a separate piece of apparatus were to be made for the purpose of measuring these powers, a positive ocular with micrometer attached would doubtless be preferred, it being placed by means of the drawtube or some other contrivance at such a height that its micrometer should be ten inches from the objective. Its reading would then give the real size of the image formed at that distance by the objective, and the ratio of this number to the known size of the object, say the distance apart of two lines on a stage micrometer, would give the magnifying power of the objective. But as few are possessed of a large variety of apparatus, or care to buy a piece for so infrequent a use as this, the measurement is generally made with an arrangement which every microscope ought to include, a negative ocular with a micrometer in the focus of its eye-lens, whose advantages for general micrometry are so well understood, giving the best view of the object and a sufficiently good view of the measuring lines, that it is usually preferred for that purpose. Of course the field lens is removed in measuring the power of the objective alone,‡ but replaced for ordinary work. If it should be thought best to name lenses by their magnifying power alone, the power ascertained could be at once attached to the lens, the present one-inch lens becoming No. 10, or x 10:§ but if it should be the usage to name it by its power when combined with some standard (say two-inch) ocular, it would be marked No. 50, or x 50, or perhaps x 45 or x 55. Should it be preferred to retain the nomenclature by inches of focal length, a power of ten diameters might be called a one-inch lens, and powers above and below rated in proportion. This plan is within reach of the opportunities of every microscopist, while the plan of actually employing a single lens of small aperture and exactly one-inch focus as a standard of comparison is only adapted to the use of

* The measurement of the image, formed by the objective only, on a screen at a distance of several feet, as employed by Dr. J. J. Woodward at the Army Medical Museum at Washington, is unquestionably the most reliable method of determining the amplifying power; but is a method which requires too many applications and too much skill to be universally applicable.

† The convenience and growing popularity in this country of this continental term suggest the propriety of its general substitution for the awkward name eye-piece.

‡ Dr. J. J. Higgins in the American Naturalist, Dec., 1870, p. 628.

§ It might be 9 or 11, and thus the various degrees of power would be conveniently expressed.

the opticians and is not free from question as to what standard is meant after all. The lens made as a standard is probably not a one-inch lens at all (principal focus), for the principal focus is never used in the microscope; and authorities differ as to whether it should have conjugate foci of one-inch and ten inches, or ten inches apart (one-inch and nine inches). Assuming x 10 as a one-inch power, would be most easily applicable and unmistakable; and this power, ten, divided by the ascertained power of any ocular or objective would give the equivalent focal length of that objective or ocular without comparison and beyond dispute.

The chances of error in this case are the same as in ordinary micrometry, with one or two additions, and should in all cases be ascertained in order to test the reliability of any series of observations. They are due to the uncertain value of the divisions of the stage micrometer, to the like (but less important) variability of the measuring scale, to the uncertainty as to the exact optical correspondence of the lines selected for comparison in the two scales, and to the uncertainty as to obtaining exactly the assumed distance between the upper scale and a given point of the objective. The first of these errors is the largest, and its magnitude would surprise many who have noticed and admired the remarkable "perfection" of the common micrometers. A micrometer which ought to be the best in the writer's possession, with lines 100, 1000 and 2000 to the inch, has a certain error of .02 and a limit of error of .035. This is entirely too much latitude for a single source of error, and of course it is nearly eliminated by comparing a large number of spaces belonging to at least several different scales, rejecting any scales which by differing widely from the average standard are presumably erroneous, and averaging the rest. The remaining sources of error may be similarly reduced by averaging, though their aggregate limit of error, ascertained by comparing the average measurements with extreme figures beyond which there is no possibility of doubt, will be found to be very small and inconsiderable.

The standard *distance of measurement* in estimating magnifying powers may be stated to be, at present, ten inches. The distance of five inches has been recommended, even somewhat recently,* and eight,† nine,‡ and ten § inches have been successively used.

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* Brocklesby, N. Y., 1851.

† Baker, Lond., 1742.

‡ Martin Fokes, Esq.. P.R.S., 1742.

§ Lardner, Carpenter, Suffolk, etc.

The smaller numbers were evidently too small, and the last, ten inches, seems to be permanently accepted as most correct theoretically and most convenient in use. If, however, the metric system were to come into general use, this distance would be changed to two hundred and fifty millimetres with increased convenience and with a scarcely appreciable difference in results. The sooner such a change is made the better, provided it is certain to come at all, and possibly it might be considered only a fair concession to the convenience of the great number of continental microscopists, and to the excellence of their metric system, to make this change without further delay.

The propriety of measuring the image at this standard distance, when estimating the power of objectives or oculars is undisputed, and it would seem equally undisputable that the whole power of the compound microscope should be obtained in the same manner, were it not that the authorities have always differed in regard to the subject. When Hooke, Griffith, Hogg, and other eminent authorities have directed that the image should be measured at the distance of the object on the stage, and Lardner, Carpenter and Suffolk, in common with most microscopists, measure the image ten inches from the eye wherever the object may be, it is useless to appeal to authorities. It would seem, however, that the former direction, to measure the image at the distance of the object, must be an advertency which could lead only to confusion. The writer has fully stated this question in a recent review,* and therefore omits further discussion of it here.

A more difficult question is as to the *point in the objective from which the measurement should be made.* If the objective had an optical centre and we could find it, there would be no difficulty in the case. But the modern objective has no permanent optical centre, at least none that we can easily find and use, and unless some one can give us a better rule, we may be obliged to measure from the bottom of the whole system, or from (about) the centre of the lowest pair or set of lenses. Mr. Charles R. Cross† has proposed to evade this difficulty by measuring ten inches between the conjugate foci used, without regard to the position of the objective; a plan which would be very eligible with high powers, but inconvenient if not inapplicable with low powers, since few compound

* The American Naturalist, June, 1871, p. 229.
† Boston, 1870.

microscopes have a body short enough to bring the conjugate foci within ten inches of each other with very low objectives, and, if they did, the magnifying power, instead of being that generally used, would be greatly reduced or altogether suppressed.

The very low power objectives (say four and five-inch) are usually mounted short in order to leave sufficient room between them and the stage, and their power as ascertained by an arbitrary rule, would be greater than that at which they are usually worked, unless, in their ordinary use, the draw tube were habitually raised enough to compensate for the shortness of their mounting.

At what point of *screw-collar adjustment* the angular aperture and the magnifying power should be computed, is one of the most complex questions involved in the discussion, and an entirely unsettled one. Most makers state the angular aperture of their lenses at its highest point, but no such uniformity of usage exists in regard to their magnifying powers.

With the lenses of a dozen years ago this would be comparatively unimportant, but with many of the high-power and high-angle lenses of the present day, the effect of the screw-collar movement is too great to be disregarded. It has been proposed, and would be most easy, always to rate objectives at their arrangement for uncovered objects, this being a naturally fixed point, and the only one at which the maker's judgment in regard to the accuracy of the correction is usually known: but this usage would greatly underrate many of the high objectives. On the other hand, rating them at their highest adjustment, or at an average between the two, might be vitiated by the fact that the point of highest correction is not a natural and fixed one, but is somewhat dependent on the judgment or caprice of the maker, some lenses of equal power being capable of a much larger range of corrections than others are. And finally, if we could agree upon some standard thickness of glass, and the glass were sufficiently uniform in refracting power, the same standard would scarcely be convenient for all powers (low powers being generally worked by the great majority of microscopists through glass, say $\frac{1}{100}$ or $\frac{1}{125}$ inch, for which many high powers are incapable of good adjustment), and few microscopists are sufficiently expert in the use of the screw-collar to make the same adjustment from the same glass-cover. Adopting the highest point of adjustment would perhaps involve the least change from present usage; and in cases of unusual interest or

importance it might be well to give both extremes, or else to specify the angle and power at which the combination was worked to accomplish the results specified. Attention need hardly be called to the fact that this great increase of power and angle, amounting sometimes to more than one-half of the minimum amount, is due entirely, not to the interposition of the cover-glass or other medium, but to the change in the relations of the lenses caused by the movement of the screw-collar. Where an extra front of different properties is added, we have essentially another objective whose power and angle should doubtless be separately stated.

The use of *linear measurement* in recording and stating powers has become so general that there may now be said to be no respectable deviation from the custom. In the early history of microscopy, powers were generally stated, according to the visible flatness or depth of the object, in superficial or cubical measure and it was plausibly urged that this represented the real, visible enlargement of the natural object; but, aside from the inconvenience of the large and often incomprehensible numbers thus obtained, this method gives in one sense the magnifying power, but in no sense the microscopical power employed. The power to see small things depends, so far as real or apparent size is concerned, on the distance from each other of minute points of structure, and this is in the exact ratio of the linear magnifying power. Squaring or cubing this power has acquired a suspicion of sensationism, if not of charlatanism, and is generally avoided in science.

If anything could be more confused and confusing than the different real and nominal powers of the objectives, it would be the corresponding powers of the *eye-pieces* or oculars. Made without any pretence of uniformity, and named without any serious attempt at significance, it has seemed until recently that no escape from the confusion was to be looked for. Yet it would seem to be convenient and altogether unobjectionable to have the oculars so named as to express their magnifying power, and the practice of doing this has been already introduced into this country. Some microscopists have re-named their oculars by their magnifying power, on the basis of one-inch to ten diameters, and I am informed by Mr. Bicknell that Tolles has already adopted the same plan, in naming those of his manufacture, discarding the letter nomenclature (A, B, C, etc.) and selecting 2 in., $1\frac{1}{2}$ in., 1 in., $\frac{3}{4}$ in., $\frac{1}{2}$ in.,

$\frac{4}{10}$ in., and $\frac{1}{4}$ in., giving powers of 5, $7\frac{1}{2}$, 10, 15, 20, 30, and 40 diameters. The writer has applied the same names to his oculars, applying the intermediate fractions $\frac{8}{10}$ in., $\frac{2}{3}$ in., and $\frac{1}{3}$ in., to intermediate powers; and he is satisfied, by experience of its convenience, that this nomenclature only needs a trial, to secure its adoption by all who use the microscope for other purposes than amusement. Of course any microscopist, having determined the power of an objective and the powers of the microscope when that objective is used with his various oculars, can obtain the powers of his oculars by dividing the latter numbers by the one first named, and can then name his oculars, like the objectives, either by their magnifying powers or by their equivalent focal lengths. The rivalry of makers and the interests of trade are not involved in this case as in that of the objectives, and there may be no reason why this plan, if as acceptable to microscopists generally, as it has been to a few, should not come into immediate use.

In order to work the objectives and oculars at their standard powers they should be of course, about ten inches apart either by length of compound body or by use of draw tube ; and it is believed that most objectives whose corrections are accurate enough to show any difference will work best at about this distance. Should a decidedly different distance be used in any observations of importance, it would be well to state that fact in recording the observation.

In reviewing this subject, the following *points* would seem to be reasonably well *settled.* Objectives should be, and could be to a much greater extent than they now are, rated according to a uniform standard. They should be named not arbitrarily, but in a manner indicative of their magnifying power. Ten inches is the standard distance of measurement in estimating powers. This distance should be taken from the eye to the rule by which the measurements are made, without regard to the distance of the object on the stage. Magnifying power is always stated in linear measure. The magnifying power and angular aperture, as well as the maker's name, should be engraved on all objectives, and added to all particularly important drawings made by their means. Oculars should be named, like the objectives, in such manner as to indicate their magnifying powers or equivalent focal lengths.

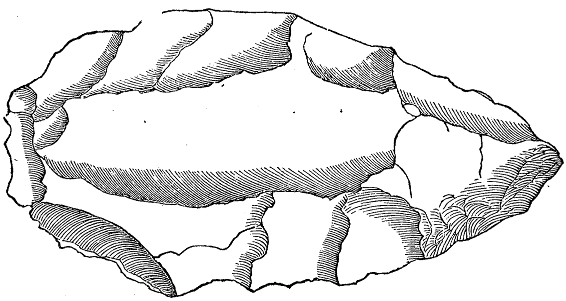
The following are some of the more important *queries* which still remain *open.* Should the standard one-inch objective be charac-

terized by magnifying ten diameters as used in the compound microscope, or should it be compared to a simple lens of actually measured focus or foci? Should the objective be named by its equivalent focal length, or by its amplifying power, or both? Should our standard distance of measurement be changed from ten inches (254 millimetres) to nine and five-sixths inches (250 millimetres)? From what point in the objective shall the distance to the scale be measured? At what point of screw-collar adjustment shall the objective be placed for rating its angular aperture and amplifying power? Should the name *ocular* be substituted for "eye-piece" in general use?

THE STONE AGE IN NEW JERSEY.

BY CHARLES C. ABBOTT, M.D.

Fig. 9.



1-2 natural size.

THERE are many people still living who remember the Indians in New Jersey, the last remnant of the once mighty tribe, the Lenni Lenape; and to-day scattered all over the state, from the mountains of Sussex to the sea-beach of Cape May, are to be found stone weapons and implements, popularly considered as once the property of these aborigines, and by them fashioned in all the varied shapes, sizes and of the various minerals that we now find. Axes, arrow-heads, lance-heads, javelins, harpoons, spears, knives, scrapers, hammers, adzes, mortars and pestles, pipes, amulets and puzzling shapes of chipped jasper; all these, in varying numbers are